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An experimental study using manipulated photographs to examine interactions between micro-scale environmental factors for children's cycling for transport

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ABSTRACT

Installing cycling infrastructure well-separated from motorized traffic is hypothesized to increase children's transportation cycling. However, in some streets it may not be possible to install such cycling paths (e.g. due to financial or space constraints). The current paper investigates which physical factors could increase parents' perceptions of environmental supportiveness for children's transportation cycling, across six different types of cycling infrastructure.

Parents completed a choice-based conjoint task by indicating which photographed street they preferred to let their child cycle along. The streets were experimentally manipulated on 7 physical factors (e.g. traffic speed, vegetation). Interactions between type of cycle path and the other environmental factors were identified.

When no or limited separation from motorized traffic is present, street characteristics increasing parents' safety perceptions (traffic density and speed) should be prioritized when aiming to improve the supportiveness of streets for children's transportation cycling. Comfort and aesthetics can further improve streets' environmental supportiveness when cycling paths are more separated from traffic.

1. Introduction

Obesity levels have never been so high as currently observed (Collaboration, N.R.F, 2016). Efforts are needed to stimulate the population to be active, especially at a young age, as children will be the next generation of adults. Increasing children's cycling levels might contribute to increasing children's physical activity levels (Cardon et al., 2012), which have shown a remarkable decrease during the last decades (Ortega et al., 2013). Children who cycle at a young age are also more likely to cycle as adolescents and adults (Cardon et al., 2012). Increasing cycling among children can enhance their health and induce a shift from extensive car use to active modes of transport that would also have ecological and economic benefits (Woodcock et al., 2009). Worldwide, researchers have observed large differences in cycling levels among children. For example, in Flanders, Belgium, boys and girls aged 10–12 years old cycle on average 25 and 27 min, respectively, to school (Brug et al., 2012). This is lower than European cycling countries such as Denmark and the Netherlands, but it is much higher than in the U.S. or Australia (Commission, E, 2013; McDonald, 2012). Increasing cycling levels should therefore considered as one of the key health strategies worldwide, as it can save many health cost, improve quality of life, lower CO_2 emission, and prevent further global warming (Mason et al., 2015). Before installing interventions aimed at increasing children's cycling for transport, it would help to learn what physical changes would likely affect cycling (Baranowski et al., 1998).

Socio-ecological models emphasize the importance of physical environmental factors next to individual and social environmental factors (Sallis and Owen, 2015). During the past decade, researchers have tried

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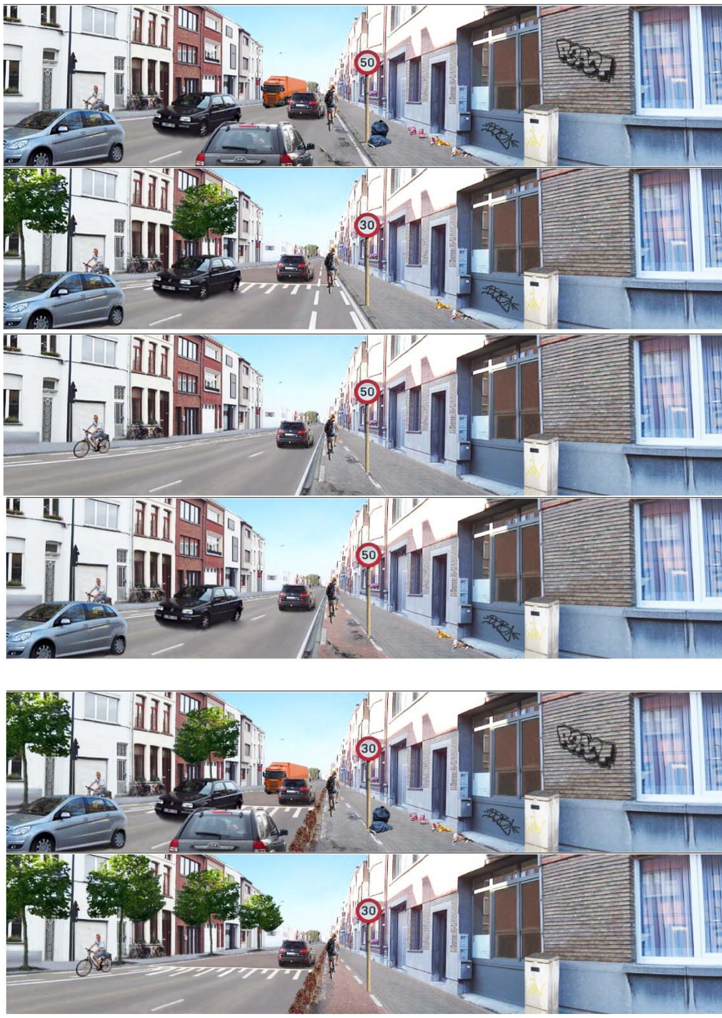

Properties of the photographs		
Cycle path: no Traffic density: high Maintenance: bad	Evenness: very uneven Vegetation: no trees	Traffic speed: 50km/h Speed bump: absent
Cycle path: marked lines Traffic density: intermediate Maintenance: moderate	Evenness: even Vegetation: some trees	Traffic speed: 30km/h Speed bump: present
Cycle path: curb Traffic density: low Maintenance: good	Evenness: moderately uneven Vegetation: no trees	Traffic speed : 50km/h Speed bump: absent
Cycle path: curb + colour with pedestrians Traffic density: intermediate Maintenance: moderate	Evenness: very uneven Vegetation: no trees	Traffic speed: 50km/h Speed bump: absent
Cycle path: hedge Traffic density: high Maintenance: bad	Evenness: moderately uneven Vegetation: some trees	Traffic speed: 30 km/h Speed bump: present
Cycle path: hedge + colour with pedestrians Traffic density: low Maintenance: good	Evenness: even Vegetation: many trees	Traffic speed: 30 km/h Speed bump: present

Fig. 1. Six examples of the manipulated photographs, which differed in 7 environmental factors. Each photograph depicts a different type of cycle path and the different levels of the other environmental factors.

to obtain insights into the physical factors explaining cycling for transport among children (Panter et al., 2008; Davison et al., 2008; Ding et al., 2011). They have found macro-scale factors such as distance to destination, connectivity of the street network and mix in land-use positively associated with children's cycling for transport (Panter et al., 2008; Davison et al., 2008; Ding et al., 2011). They have also found traffic safety important for children's cycling, but it remains unclear about which traffic safety elements to employ, because perceived traffic safety can be influenced by many small, micro-scale environmental factors such as traffic speed, type of cycling infrastructure, traffic density and evenness of the cycling infrastructure (Ghekiere et al., 2014). Parents' perceptions of safety may even be more strongly associated with children's cycling for transport, given that parents often decide whether the child can cycle for transport without adult supervision (Schoeppe et al., 2015). However, findings regarding the associations between these micro-scale, easy-to-change environmental factors are mixed, which may be partly explained by methodological issues (Ding et al., 2011).

Previous studies examining associations between physical factors and cycling for transport often used self-report questionnaires, in which they asked participants to indicate the physical features in their neighborhood, and to link those features to their transport behavior. This method has at least two problems. First, participants' recall of features in their neighborhood may be inaccurate, as they are not observing their neighborhood when completing the questionnaire. Second, people may interpret their neighborhood differently, such that without a definition, the researchers cannot know what area they measured. To study which physical factors are most important for parents to create a cycling-friendly environment for children, an experimental study using manipulated photographs was set up recently (Ghekiere et al., 2015a). The use of manipulated photographs can overcome the aforementioned limitations, as they neither need a neighborhood definition nor do they need to have participants recall physical features of their neighborhood. Studies have tested the feasibility of this approach in several studies (Ghekiere et al., 2015a, 2015b; Mertens et al., 2014, 2015, 2016; Van Cauwenberg et al., 2014; Cauwenberg et al., 2016; Van Holle et al., 2014). Parents were repeatedly asked to choose one out of two hypothetical streets they prefer to let their children cycle along. These streets were created with the use of a standardized photograph manipulated on seven physical features previously found to be important to create a supportive environment (Ghekiere et al., 2014).

We identified that having cycling infrastructure which adequately separates cyclists from motorized traffic is by far the most important strategy for parents to create supportive environments for children's cycling for transport (Ghekiere et al., 2015a). A physical separation from traffic by a hedge was preferred over separation by a curb or a separation by line markings, which in turn were preferred over a shared path for cars and cyclists (Ghekiere et al., 2015a). Other environmental factors, such as traffic speed, maintenance and vegetation, were subordinate to the presence of well-separated cycling infrastructure. However, providing these well-separated cycling facilities in each street may not always be possible due to practical or financial constraints. Additionally, a particular physical factor may vary in its importance in the presence of specific cycling infrastructure. In Flanders, as well as in Canada, parents represent the decision-makers on 10- to- 12-year-old children's cycling for transport (Faulkner et al., 2010; Ghekiere et al., 2016), and, therefore, the present study centers on them. It sought to find out which micro-scale physical factors could increase parents' perceptions of the environment as supportive for their children's cycling for transport, across six different types of cycling infrastructure.

2. Methods

The study protocol has been reported elsewhere in full detail (Ghekiere et al., 2015a). Briefly, parents were recruited via children from the 5th and 6th grade (aged 10–12 years) across 45 primary schools in Flanders, Belgium. Between November 2014 and January 2015, parents were asked to complete an online questionnaire. Informed consent was automatically obtained from the parents when they voluntarily completed the questionnaire. The Ethics Committee of Ghent University Hospital approved the study protocol (EC/075-2015/mf).

A choice-based conjoint (CBC) task was integrated in the questionnaire. Parents were asked to choose between two potential cycling routes depicted on a photograph, and to indicate which route they preferred most to let their child cycle along to a friend living 10 min from their residence without adult supervision. These photographs were experimentally manipulated on seven environmental factors in Adobe Photoshop (see Fig. 1): type of cycle path (6 levels), cycle path evenness (very uneven, moderately uneven, even), traffic speed (50 vs. 30 km/h), traffic density (high, intermediate, low), amount of vegetation (many, some, no trees), speed bump (absent, present) and maintenance of the street (good, moderate, bad upkeep) (Ghekiere et al., 2015a). Photographs including all possible combinations of environmental factors were created, resulting in 1944 photographs. In Fig. 1, examples of photographs are provided, in which the different manipulations of the seven environmental factors are presented. The first photograph was considered to be the worst situation (all environmental factors in the least favorable level), the last was considered the best situation.

2.1. Analysis

Significant interactions between type of cycle path and the six other environmental factors were identified by the CBC Interaction Search Tool in Sawtooth Software (Orme, 2016). Six models were fitted, including the main effects of the seven environmental factors and one interaction effect between cycle path and one of the six remaining environmental factors. Hierarchical Bayes estimation was applied to calculate relative importances (RI) as recommended (Orme, 2006). A relative importance represents the impact of each environmental factor on the choice for a particular route within each type of cycling infrastructure (Orme, 2006). Confidence intervals (95% CI) were calculated to assess significance.

3. Results

Of the 2461 parents who received an invitation to participate, 1289 completed the choice-based conjoint task (response rate = 52.4%). Participants were mainly mothers (77%), married (72.8%) and were parents of boys (49.4%) and girls (50.6%) from fifth (47.5%) and sixth grade (52.5%).

Five significant interactions were found, between cycling infrastructure and (1) evenness of cycle path, (2) maintenance, (3) presence of a speed bump, (4) traffic speed and (5) traffic density (see Fig. 2). No interaction was found with amount of vegetation.

When *no cycle path was present (C0),* traffic speed was by far the most important factor to choose for a specific cycling route, followed by maintenance and traffic density. Presence of a speed bump was least important. Traffic density was the most important factor *when a cycle path with marked lines (C1)* was present, followed by maintenance of the street and evenness of the cycle path. Furthermore, traffic speed was more important than vegetation and speed bump. When cyclists were *separated from traffic by a curb (C2)*, traffic density was also the most important factor, followed by traffic speed, maintenance, evenness and vegetation, although the differences in importance of the environmental factors were smaller compared to C1. When a *cycle path segregated from traffic by curb and from pedestrians by color (C3)* was present, maintenance was the most important factor, followed by traffic speed, traffic density, evenness, speed bump and vegetation. When a *cycle path separated from motorized traffic by a hedge (C4)* was present, evenness was the most important factor, followed by maintenance, traffic density, traffic speed, vegetation and speed bump. Finally, *when cycle paths separated from traffic by a hedge were also separated from the pedestrians by color (C5)*, traffic speed and maintenance were the most important factors, followed by traffic density, vegetation and speed bump.

4. Discussion

Recently, a study using manipulated photographs showed that parents would prefer their child to cycle on routes with cycling infrastructure well separated from motorized traffic (Ghekiere et al., 2015a). Installing cycling paths does not only have the potential to increase the perceived supportiveness of an environment, but recent studies also indicate that it may increase cycling for transport levels as well (Goodman et al., 2014; Parker et al., 2013).

Traffic safety-related factors, such as traffic density and traffic speed, were most important cycling-paths had limited or no separation from motorized traffic. This suggests that in situations where cars and cyclists share the same road, one should keep traffic speed low, preferably 30 km/h or less. When cycling paths had some separation from traffic (through curbs or lines), lowering traffic density (e.g., by allowing only one-way traffic) emerged as most important. When cycle paths had a physical separation from motorized traffic, such as a hedge, the importance of comfort and aesthetics increased; maintenance of the street and vegetation were more important in streets with a cycle path separated from traffic by a hedge (C4 and C5) compared to the other types of cycling infrastructure. These findings also emerged in a study using the same method among a sample of Flemish adults (Mertens et al., 2016). They suggest that perceived traffic safety is a prerequisite to create a supportive environment, and other features not influencing safety can improve the environment, to a lesser extent, for parents in deciding whether their child may cycle independently.

Findings from this experimental study should be interpret in the right context. The experimental use of manipulated photographs overcomes several limitations of previous (mainly cross-sectional) survey studies. This method allows for the study of many physical factors simultaneously. This mimics real life situations, where cyclist need to decide which cycling route they will take considering all physical factors they encounter. Additionally, it does not require the participants to recall particular features within its neighborhood as needed when completing surveys. Instead, they see and respond to the physical features in a typical (semi-)urban street in Flanders, Belgium, and do not need a definition of neighborhood (Mitra and Buliung, 2012) (cfr. modifiable areal unit problem). Finally, integrating these manipulated photographs into a choice-based conjoint task did not require participants to rate or rank all 1944 photographs. Instead, from 12 choices (a major reduction in effort and more feasible approach), we could obtain a ranking of importances for each physical feature.

Nevertheless, the present approach has at least four kinds of limitations. One relates to behavior, a second to the photographs, a third

Type of cycle path	**C0**	**C1**	**C2**	**C3**	**C4**	**C5**
						
Importances of the micro-scale environmental factors	Traffic speed (31.3%; 30.7-31.9)	Traffic density (27.1%; 26.5-27.8)	Traffic density (22.7%; 22.1-23.2)	Maintenance (25.5%; 25.0-26.1)	Evenness (25.3%; 24.7-25.8)	Traffic speed (21.4%; 20.7-22.0)
	Maintenance (17.1%; 16.7-17.5)	Maintenance (20.5%; 19.9-21.0)	Traffic speed (18.1%; 17.6-18.6)	Traffic speed (19.6%; 19.1-20.2)	Maintenance (21.0%; 20.5-21.6)	Maintenance (21.2%; 20.6-21.9)
	Traffic density (16.2%; 15.6-16.8)	Traffic speed (14.1%; 13.7-14.5)	Maintenance (16.8%; 16.2-17.3)	Traffic density (16.8%; 16.3-17.3)	Traffic density (19.0%; 18.3-19.6)	Traffic density (19.0%; 18.4-19.6)
	Evenness (13.2%; 13.0-13.5)	Evenness (17.5%; 17.0-18.0)	Evenness (16.4%; 15.9-16.9)	Evenness (16.2%; 15.8-16.6)	Traffic speed (16.9%; 16.3-17.4)	Vegetation (17.2%; 16.7-17.7)
	Vegetation (13.0%;12.7-13.2)	Vegetation (12.2%; 11.8-12.6)	Vegetation (15.9%; 15.5-16.4)	Speed bump (11.6%; 11.2-12.0)	Vegetation (12.5%; 12.2-12.8)	Evenness (15.0%; 14.5-15.6)
	Speed bump (9.2 %; 9.0-9.5)	Speed bump (8.5%; 8.2-8.8)	Speed bump (10.1%; 9.8-10.5)	Vegetation (10.2%; 9.9-10.5)	Speed bump (5.3%; 5.1-5.6)	Speed bump (6.2%; 5.9-6.4)

Fig. 2. Relative importances and 95% confidence intervals for each micro-scale environmental factor within the six different types of cycle path.

relates to the population, and a fourth relates to other non-physical factors. Regarding behavior, the survey asked parents to indicate which cycling route they preferred, but the study did not link that preference to actual behavior. Research could explore the degree to which the expressed preferences predict the routes, or characteristics of the routes, that the children take. For example, it could compare the physical characteristics rated as most important by the parent to the physical characteristics of the most often used cycling routes among the children. Studies using this choice-based conjoint approach could also ask the participants whether they would actually cycle in real life in the situation they preferred. The use of this approach was recently tested among adolescents to indicate their preference for cycling-environments (Verhoeven et al., 2017) and their preference for park characteristics (Van Hecke et al., 2017). Regarding the photographs, although research indicates that preferences for photographs generalize well to on-site responses (Stamps, 1990), virtual reality simulations could allow the introduction of realistic conditions such as three dimensions, movement, and noise, while allowing the same experimental control possible through photographs. The photographs also had some conditions, such as weather, crossing, and roundabouts, constant. Although planners do not control weather, it might be useful to test the stability of the present findings through the same simulations tested in different weather conditions. Studies could also consider which factors create cycling-friendly crossings and roundabouts. As for population, research could test responses in other countries, with lower cycling rates, and for other more diverse populations around the world. Finally, while studying physical factors that might support children's cycling, the present study did not examine non-physical factors that might affect children's cycling for transport. Socio-ecological models suggest that individual and environmental factors interact with each other to explain particular behaviors (Sallis and Owen, 2015). In trying to understand the complexity of travel behavior, we call for more studies explore the extent to which individual and environmental (including physical and social) factors explain the observed variance in cycling levels among children, and studies that examine interactions between these factors. Such research may reveal whether the importance of a particular physical factor varies with individual characteristics (such as cycling skills, gender, age, maturity, presence of friends/parents along the route).

To summarize, the findings suggest that priority should be given to providing well-separated cycle paths to improve parents' perceptions of environmental supportiveness for children's cycling for transport. When installing physically separated cycle paths is not feasible and no or only limited separation with motorized traffic is possible to provide, factors affecting parents' perception of safety should be prioritized (i.e. traffic density and traffic speed). When separated cycle paths are available, aesthetics and comfort-related factors could further improve the supportiveness of a street for children's cycling for transport.

Competing interest

The authors declare that they have no competing interests.

Authors' contribution

AG, LM, JVC, IDB and BD drafted the concept of the study. AG and LM performed data collection. AG analyzed the data and drafted the manuscript. All authors critically reviewed and approved the final version of the manuscript.

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